Use direction-finding to trace interference

Pick the direction-finding technology you like the best and learn to use it. When the time comes and you have an urgent need to track down a signal, it will be too late if you haven't had some practice.

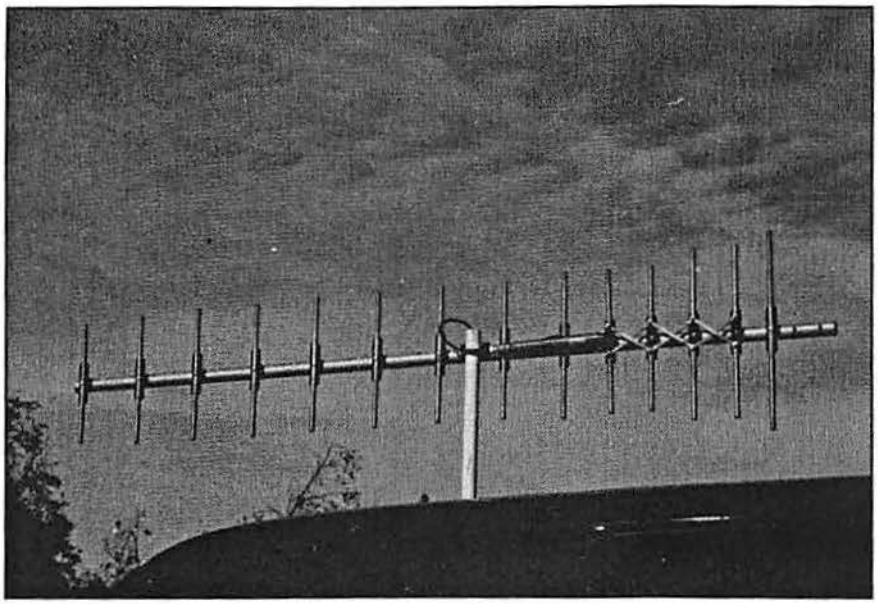

Photo 1. A simple, inexpensive way of taking a bearing to a signal from a mobile unit. This broadband yagi gives first-rate results from 450MHz to 470MHz. It rotates on a mast that protrudes from the vehicle window or through a hole in the roof. As the beam antenna is turned, usually by hand, a signal strength meter (S-meter) on the receiver indicates when the antenna points in the direction of the strongest signal.

By Joseph D. Moell, P.E.

There it is again! That strange carrier, interfering with your radio system. There is no modulation to identify it. Where is it coming from? How do you find the source?

Radio direction-finding (RDF) techniques used to trace the source of interfering signals were developed in the early days of radio communications. Today, the military, the FCC and search and rescue agencies, such as the Civil Air Patrol and the U.S. Coast Guard, make heavy use of RDF.

Few radio shops are well equipped for efficient RDF. But you, as a radio technician or system operator, can put RDF to good use on your own behalf or on behalf of agencies and other customers you serve. Here are some examples:

• *Stuck transmitters*—Whether caused by equipment malfunction or by a user who sits on a hand mic, a continuous carrier on your frequency may halt all communication. The source must be found—fast. If automatic number identification is not in use and no audible clues are heard, multiple-site RDF makes tracing the source much easier.

• *Stolen radios*—It is not uncommon for a lost or stolen hand-held or mobile radio to appear on the air, causing interference and harassment. An RDF network provides the best chance of rapidly stopping the interference and recovering the radio.

• *Surveillance*—RDF can locate criminals who use radios to coordinate their activities. Vehicles and sensitive cargo can be tracked on the move, without exposing officers to view. Tiny, remotely activated "bumper beeper" transmitters serve the purpose.

• *Lost individuals*—Mass media publicize the use of RDF to track emergency locator transmitters (ELTs) carried by aircraft and emergency position indicating radio beacons (EPIRBs) carried by boats. But sometimes, lives must be saved by tracking other transmitters.

Last year, when a single-engine airplane crashed in rugged terrain west of Denver, its avionics were destroyed and its ELT failed to activate. The pilot and passenger, both radio amateurs, used hand-held amateur VHF transceivers to call for help.

Three other amateur operators skilled in RDF quickly used their direction-finding equipment to determine the airplane's location. Evacuation of the two crash victims was complete within six hours.

• *Intermod products*—Although you may be able to listen to the offending intermod signal and identify the two-or-more mixing frequencies from the in-

Moell is head of the Transmitter Subsystems Section at Hughes Aircraft, Fullerton, CA. He is co-author of *Transmitter Hunting—Radio Direction Finding Simplified* (stock No. 2701); TAB Books, Blue Ridge Summit, PA 17294-0214. The 323-page handbook includes practical techniques and circuits for RDF.

formation it carries, knowing the frequencies does not necessarily pin down the source.

In Southern California, a strong mixing product interfered with a communications satellite downlink. The signal's components came from a noncommercial FM station and a VHF TV station's aural carrier. Both stations are on mountaintop sites. But RDF showed that the mix occurred at an industrial area 25 miles from the mountain!

Calling for help

Why not just call the FCC for direction-finding service? The commission's field offices have sophisticated RDF equipment for many frequencies.

Unfortunately, the agency cannot guarantee a rapid response. Staff reductions and higher-priority requests for RDF capability, such as those involving critical government communications, may make the FCC's RDF capability unavailable to you when you need it.

It is far better to be prepared to hunt interference sources on your own.

You can simply wander around your coverage area, listening for a strong signal to indicate the transmitter you seek is close by. That is the so-called "hot-cold" method of transmitter hunting. A better name would be the "needle-in-a-haystack" method. It is not radio direction-finding, because there is no indication of direction. You need something that gives a bearing to the signal—a directional antenna—and you may have one already.

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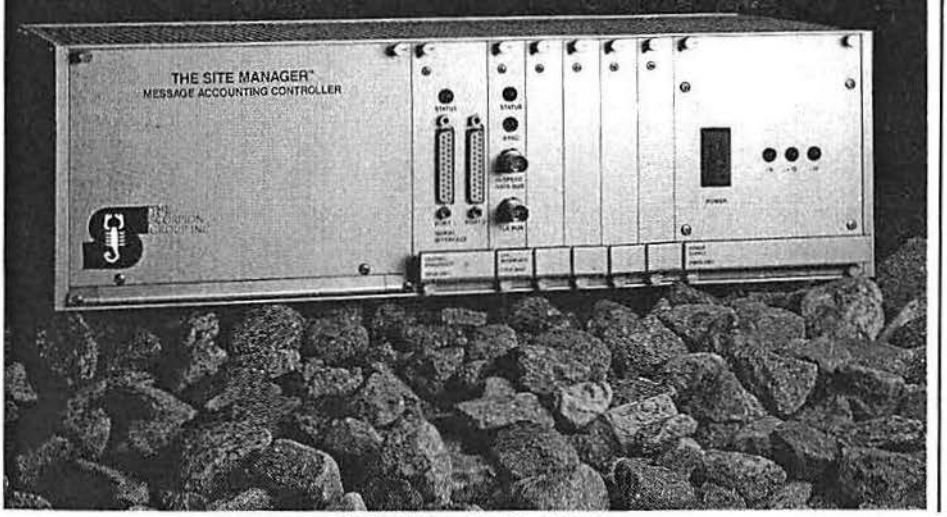

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FCC enforcement priorities

- ☐ White House and presidential communications
- ☐ Communications involving safety of life and property
- ☐ Public safety and commercial communications
- ☐ Other

Yagi and quad antennas (beams)

Photo 1 on page 18 shows a simple, inexpensive way of taking a bearing to a signal from a mobile unit. Mount a yagi or cubical quad antenna on a rotating mast that protrudes from the vehicle window or through a hole in the roof. As the beam antenna is turned, usually by hand, a signal strength meter (S-meter) on the receiver indicates when the antenna points in the direction of the strongest signal.

Aluminum yagis are readily available and easily mounted. You may have extra yagis that can be pressed into service.

Quad antennas (See Photo 2 on page 22) can be made of stiff copper wire and PVC plastic pipe. Construction time is about two hours, plus time to modify the vehicle to attach the rotating mast and some sort of pointer and compass rose at the mast base.

The larger the beam, the better the bearing resolution. Usually four ele-

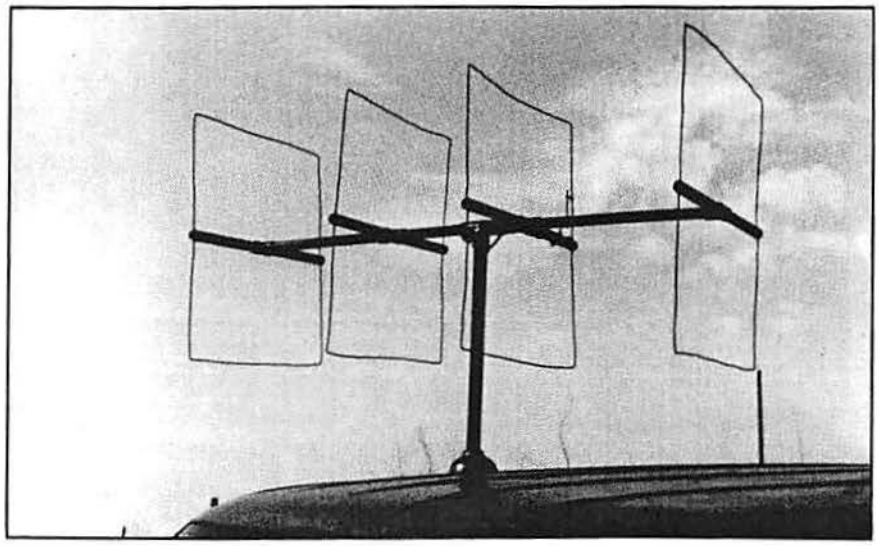

Photo 2. Cubical quad antennas can be made of stiff copper wire and PVC plastic pipe. Construction time is about two hours, plus time to modify the vehicle to attach the rotating mast and some sort of pointer and compass rose at the mast base.

ments on VHF highband is a reasonable number for suitable bearing accuracy and ease of turning. Frequency bandwidth for adequate directional performance is no greater than 10%. Thus, more than one beam antenna may be required to cover all frequencies.

You need an S-meter on the receiver to determine accurately when the beam is pointing at the signal source. External S-meters can be added easily to receivers that do not have them.

Because FM receivers saturate in the presence of extremely strong signals, an external attenuator is a must. The attenuator reduces signal input to the receiver as you come closer and closer to the signal source.

Polarization

The orientation of the yagi elements and of the quad's feedpoint determines polarization. Your RDF beam must be polarized the same as the signal source to reduce adverse effects of multipath reflections.

Most land mobile transmitters use vertically polarized antennas. But intermod mixing points and transmitters in the broadcast and other services may have predominantly horizontal polarization. Make provisions for rotating the antenna boom to select between vertical and horizontal polarization as necessary.

The main advantage of a gain RDF antenna is its high sensitivity. When the signal is weak, a beam antenna outper-

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Photo 3. Homing RDF units use a pair of vertical antennas at the ends of a horizontal boom. The antennas are separated by less than a half-wavelength. The SuperDF made by BMG Engineering works on foot, or can be used this way on a vehicle.

forms other RDF methods. When you must find the source of a feeble spurious emission that just barely holds your hilltop receiver open, the beam antenna is your best bet.

Beams are unsuitable for use below 100MHz. Yagi elements for 33MHz VHF lowband are about 14 feet long. That length is not practical for the average squad car!

Other problems associated with beams are their requirement for manual turning. Manual turning, together with the usual signal flutter in mobile service, makes taking bearings a practiced art, particularly on intermittent signals. Having two individuals, one to drive and one to rotate the antenna, gives maximum efficiency.

Homing-type RDF sets

Homing RDF units use a pair of vertical antennas at the ends of a horizontal boom. The antennas are separated by less than a half-wavelength (See Photo 3 above.) The antennas are switched back and forth electronically several hundred times per second. Two types of homing RDF sets operate on different principles, but they are used the same way.

Switched pattern units, such as the L-Per made by L-Tronics, use AM receivers and determine which of two antenna patterns produces a stronger signal.

Time difference of arrival (TDOA) units, such as the SuperDF made by BMG Electronics, work only with FM receivers. They use phase techniques to determine which of two antennas is closer to the signal source.

With both units, an indicator, such as a zero-center meter or a pair of light-emitting diodes (LEDs), tells the user which way to turn the antenna, left or right. A sharp "crossover" indication reveals when the antenna is pointed ex-

actly at the signal source.

For switched pattern units, crossover occurs when signals reach equal amplitude as received by each pattern. For TDOA units, crossover occurs when the antennas are equidistant from the source.

Both types are sold commercially at reasonable prices. The L-Per comes with a built-in, four-channel, crystal-controlled receiver; an attenuator; and a meter. It is compact and comes ready to use, but you must have a crystal for the desired frequency. Frequencies can be selected in one of several bands from 120MHz to 320MHz. Prices start at about $400.

The SuperDF connects to an FM receiver or scanner, so it works over a wide frequency range: 100MHz to 260MHz on the VHF antenna and 250MHz to 550MHz on the UHF antenna. It does not need any additional crystals.

The SuperDF can be carried on foot, together with a hand-held receiver. Alternatively, its rotatable antenna can be mounted on a vehicle for use with a mobile receiver. The assembled SuperDF unit with VHF antenna is less than $300, not including a receiver.

The portability of homing RDF sets is advantageous. They are easy to set up and carry. When not in use, they can be folded up and stored in a small space in the vehicle.

Despite a lack of antenna gain, they have enough sensitivity.

Both are highly accurate in the absence of multipath. Inferior stationary multipath performance is the major disadvantage shared by these units. It is best to stay in motion to "average out" the bearing swings caused by signal reflections.

Homing RDF units sometimes give unreliable results when the signal is horizontally polarized. Special techniques must be used in such situations.

S-meters are not needed with homing RDF units, which are not swamped by strong signals. Usually, these characteristics are advantageous. But sometimes they turn into disadvantages. Because the units do not display amplitude information, the hunter may pass by the subject transmitter without noticing it. With the L-Per, overshooting the transmitter is less likely because its internal sensitivity control indicates proximity to the transmitter.

Airborne RDF

If aircraft are used in your operations, do not overlook the advantages of airborne RDF. Besides the ability to cover large areas rapidly without traffic or road problems, the use of a high platform eliminates most multipath problems that plague ground-level VHF RDF in uneven terrain. Airborne RDF really shines in search and rescue operations in rugged wilderness.

Homing RDF units, such as the L-Per or SuperDF, are ideal for airborne use because they indicate the direction to turn. Antennas can be mounted on the side of the cockpit or, less desirably, taped to the windshield.

Rotating antennas are unnecessary;

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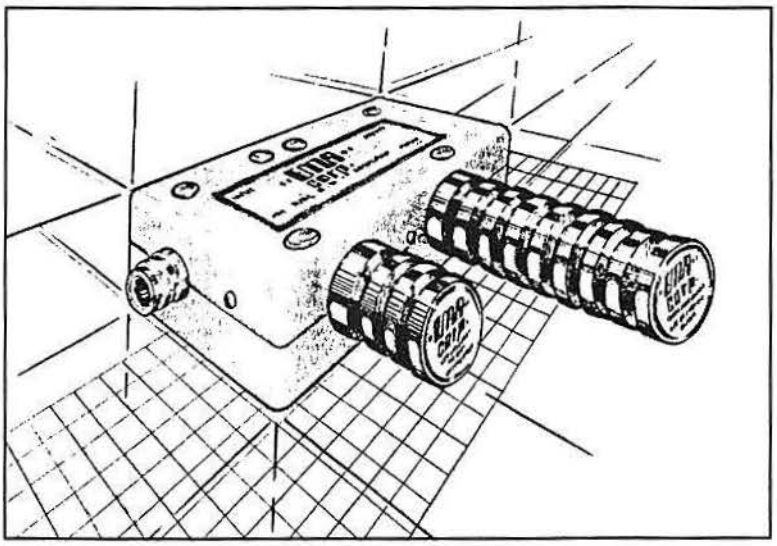

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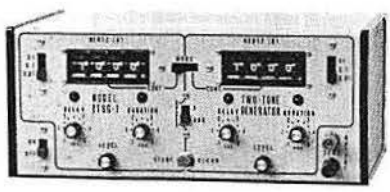

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just turn the plane! The pilot simply follows the RDF's left-right indications to fly right over the signal source. With practice, it is possible to maneuver a small plane to fly over the target with an accuracy of a few feet. Airborne RDF experts can determine from the air which car in a parking lot has the transmitter in it.

Ring antenna RDF sets

Just as there are two major types of homing RDF units, there are two types of ring antenna systems: Doppler and Adcock (sometimes called Watson-Watt). They use similar antennas and displays, but different processing techniques. One uses AM detection, the other, FM.

Ring antenna RDF units offer a major improvement in operating convenience compared to manually turned antennas. They are much easier to use, especially when hunting alone.

Ring antenna RDFs typically use a set of four or more identical vertical antennas. Dipoles are used for fixed installations. Quarterwave whips suffice for mobile use.

The mobile antenna system may be a single assembly fitted with suction cups to grip the vehicle roof, or four individual whips connected to a switcher by coaxial cable lines of equal length. Individual magnetic-mount whips work fine. Either the suction-cup or magnetic-mount version is readily moved from one vehicle to another.

Direction-finding applications

- ☐ Recovering stolen radios
- ☐ Finding 'stuck mics'
- ☐ Tracking surveillance transmitters
- ☐ Search and rescue
- ☐ Tracing intermod sources

RDFs are popular for use with marine VHF transceivers. Several companies make them, including Apelco, Koden and Simrad. Usually they are sold as add-ons for your own FM receiver, with no internal modifications necessary.

For the land-based two-way radio commercial market, Doppler Systems offers RDF sets with display and antenna for VHF highband beginning in the $800 price class, not including the receiver.

RDFs using the Adcock principle require AM detection in the receiver. Often, the receiver is sold in a package with the RDF set, but an external receiver can be used, with minor modifications. Compudyne EWI Division supplies three-channel Adcock RDF sets under the name OAR for commercial use.

Both types of ring antenna RDF sets can be provided with a digital readout of bearing in degrees, or a less expensive circular display that "points" to the signal source direction. Doppler units typically use a ring of light-emitting diodes (LEDs). Adcock units generally

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feature a cathode-ray tube (CRT) display with "vectors" pointing in the direction of signal sources.

The CRT display is superior because it clearly indicates the presence of most types of multipath. Be prepared to pay a premium for the CRT display: Adcock RDF sets generally cost several times the price of Doppler units.

Doppler and Adcock RDF units are favorites of many RDF technicians because of their rapid response. No mechanical turning is necessary, so the units display bearings even for short signal bursts. Compared to yagis and quads, Doppler and Adcock units are more broadband and are easier to install on almost any vehicle.

Some inexpensive Doppler units use PIN diodes to "hard-switch" among the antennas. In areas with high RF levels, hard switching creates noise and cross-modulation products that reduce RDF sensitivity. Doppler Systems units use sophisticated "soft-switching" antenna selection circuits that minimize cross-modulation products and maximize sensitivity.

Ring antennas are not the answer for every RDF situation. They are not suitable for hand-carrying. They cannot be used to track pulsed or non-carrier signals, such as power line interference and single-sideband signals. Readout resolution on some models is limited. Bearing error may be severe when the signal is horizontally polarized and when multipath is present. Sensitivity may be inadequate on weak signals.

Ring antennas are not the answer to every RDF situation.

Triangulation

Having read this far, you probably are convinced that equipping one of your vehicles with RDF gear could be important.

If your service area is small, one RDF vehicle might be all you need. But what if you service a large metropolitan system with satellite voting receivers, or a wide-area system with mountaintop repeaters? Your single vehicle is not likely to be in the right place at the right time to hear the source of the problem and respond rapidly.

When it is necessary to augment the single vehicle with additional RDF capability, it may be done by equipping more vehicles with RDF gear or by supplementing the mobile RDF unit with fixed RDF sites at strategic, elevated sites. Properly located base stations and vehicles can "triangulate" their bearings to reduce the search area dramatically.

Triangulation does not provide pinpoint accuracy. Bearing errors on VHF signals from elevated RDF sites can be

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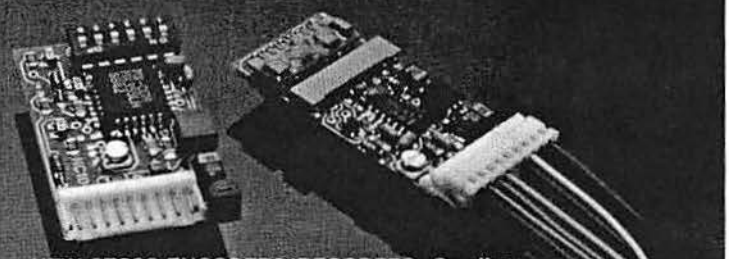

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- ☐ Beam antennas—yagis and quads
- ☐ Switched-pattern homing sets
- ☐ Time difference of arrival homing sets
- ☐ Doppler-shift ring antenna sets
- ☐ Adcock ring antenna sets

significant, depending upon the equipment used and the local conditions.

For example, atmospheric inversions and the "coastal effect" in the Los Angeles basin cause VHF hilltop bearings over land and water paths to appear to drift 15° or more in a typical day.

With three RDF sets accurate to a bearing resolution of ±10° and separated equally from one another by 20 miles, bearings to a transmitter midway between them would define an area of 13.8 square miles. Thus, hilltop sites alone are not enough for a complete RDF system, but they provide a target area for RDF vehicles.

Get started now

Whatever RDF system you decide is best for your particular needs, now is the time to obtain it and learn to use it. Do not delay. When you have need for RDF, it will be too late.

No matter how simple your chosen system seems to be, it will take some time to become familiar with its use. Terrain affects readings, so you should make trial runs to track down transmitters in known locations.

Once you are comfortable with the system operation, have someone transmit to you from an unknown location to test your RDF skills. Once you have had a few successful hunts, you will be ready when the need to track a signal to its source arises.

RDF as a sport can be lots of fun. Amateur radio operators have held RDF contests since the earliest days of radio, using new technologies as they evolve. If amateurs in your area hold weekend RDF contests (often called "T-hunts" or "foxhunts"), they may have RDF experience that can help you or your agency in setting up your RDF capability.

RDF is not usually a daily activity, but when the need arises, it may be urgent. Take time now to become familiar with RDF. When the unknown carrier comes on, will you be ready?

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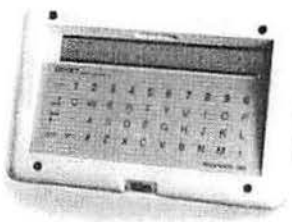

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